A Fundamental Study for Participating in Multiple Teleconferences

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Abstract. The purpose of this research is to support office workers to participate in multiple teleconferences simultaneously. In order to achieve this goal, we have investigated how people understand multiple voices that differ in conditions of overlapping rates. We have evaluated comprehension of the context and the keywords in multiple voices, which is necessary for the users to participate in multiple teleconferences. In addition, we have described the psychological load of the users by using NASA-TLX as the workload index and the physiological load by examining the brain waves of the users. From the experiment, we can show three factors. First, we found more than half of the examinees understand the context when the voices are overlapped completely. Second, little of no difference is observed in the level of comprehension of keywords, between when the voices are half overlapped and overlapped completely. Third, it can also be suggested that examinees are more uncertain of their answers when the voices are overlapped completely compared to when they are only half overlapped. As for the load of the users, our results suggested that imperfect overlap amplifies the psychological load. Based on these results, we will discuss the necessity of selecting appropriate overlap rates and design the environment of multiple teleconferences.

Keywords: multitask, multiple voices, multiple teleconferences, overlap rate.

1 Introduction

The developments of the office work techniques help employees perform tasks such as making documents and managing business. On the other hand, the speed-up of individual work and reduction in the number of workers by systematization of working has increased their workloads. To solve such a workload problem the research about workload in offices started[1]. The research shows us that many of the present IT systems are designed for neither task interference nor switching. They are only designed to support individual tasks like e-mail or preparing documents [2]. Keeping this in mind we focused on the multitasking researches.

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The multitasking researches engage two or more tasks at the same time and especially look at the combination of two tasks. We classified the office work as shown in Table 1.

Table 1. Categorizing office works

		Sub Work	
		Conversational Work	non-Conversational Work
Main Work	Conversational Work	e.g. Participating in two conferences simultaneously	e.g. E-mailing while participating in a conference
	non-Conversational Work	e.g. Listening to people's conversation while making documents	e.g. Reading documents and e-mailing simultaneously

In Table 1, we define "conversational work" as work involving live, real-time communication such as a business meeting. In conversational work, it is difficult to control the timing of interruptions. We define "non-conversational work" as work involving live, non-real-time communication such as e-mail and forming document. In non-conversational work, it is easy to control interruptions. When we consider the difficulty in the level of multitasking from the aspect of control, we hypothesize that the combination of conversational work is the most difficult combination to be engaged. We believe that thorough consideration of conversational work is the key to designing an effective multitasking system.

One of the multitasking studies discusses the necessary of the multitasking researches. They have a negative perception of it from the field of brain science because it is difficult for our brain to handle multiple tasks from the perspective of memory capacity. They also suggest that if we can handle multiple tasks simultaneously, it doesn't produce the desired effect compared to doing each task in part. That study implies the damage of memory function in our brain. However they say these results only when we handle multiple tasks by just using human pure function. And they also take a positive view of multitasking. They say it may be inevitable circumstance in the future from an institutional standpoint. So that means there's a possibility multitasking will become one of the office-work styles. To achieve the multitasking style, we try to design the multitasking system supporting human information-handling ability.

As an effort to adapt to such an environment, office workers are forced to work on two or more tasks simultaneously. One of the multitasking studies discusses the necessary of multitasking. In recent days, there is a growing need for ability to manage two or more tasks effectively while participating in other works. For example, if a person is required to attend to a meeting in which he/she only has to listen and does not have to speak, he/she might feel that it would be more productive if he/she could finish other works during the time of the meeting. In a similar way, many people may feel that it would be more productive if they could attend to two meetings at the same time. Although many serious objections to the efficiency of multitasking are claimed, we believe in the positive possibilities

of multitasking. We have been examining such multitasking studies and believe in the possibility of multitasking, even though the multitasking system is not yet widespread in the world. The future aim of our research is to create a system where the users are able to participate in two or more tele-conferences. When we assume participation in two or more teleconferences, we need not only to listen to other participants, but also to understand statements of others and respond to them. The existing research of multitasking involves the study of dual-task interfaces, visualization systems, and so on. For instance, one of the previous researches describe that how secondary displays should be shown while users work on their main task on another computer. The experiment shows us that users are required to maintain awareness of the changing color or size of character and background on the secondary display. However in such a field of multitasking, little or no research quantitatively focuses on human ability to hear multiple voices. Therefore we aim to reveal the influence of human hearing ability of multiple voices. Our study investigates the comprehension level of the users and confidence of their answers under two various voice-conditions. The results produce a possible design of a multitasking system for participating in multiple teleconferences.

This paper is organized as follows. In Section 2, previous studies related to the multitasking are presented. The details of the proposed design for the experiment are described in Section 3. The procedure of the experiment and the results of the experiment are discussed in Section 4 and Section 5 respectively. In Section 6, the evaluation of the experiment is discussed. The concluding remarks and future works are noted in Section 7.

2 Related Work

Many of the studies, which stimulated our research, stemmed from previous studies on efficiency and attention in the aspects of multitasking. Because this paper describes how users are affected their attention under two various voice-conditions and our goal is designing the effective system of multiple teleconferences, these studies are of critical interest to us.

D.Smith et al.[3] describe the efficiency of multitasking by giving tasks to participants. The tasks, such as solving math problems and classifying geometric objects, indicate that multitasking may be less efficient especially for complicated or unfamiliar tasks. This is caused by the difficulty involved in switching mental gears every time the participant changes from task to task. However, the study also says that there is the possibility of success under certain environmental conditions and that it is worth challenging. H. Schumacher et al.[4] also describe the efficiency of multitasking. The research investigated the difference of reactive time and error rate between dual-task and single-task by making participants solve both visual and oral problems. As a result, the study says that there is no significant difference between dual-task and single-task after they perform them two or more times. Although the experiment gives oral tasks to the participants,

it does not refer to anything about comprehension and imposition load in cases where participants hear multiple voices. This research stimulated our study of multitasking.

One of the important researches in the field of multitasking is the study about the dual-task system. Many of such dual-task researchers focus on visual aspects of multitasking. Since the dual-task system requires participants to switch quickly between the tasks using two visual displays, some of the previous evaluations focused on the combination of two tasks and the display of the secondary task. C.M. Chewer et al[5] analyze the rate of correct answers of various types of problems involving visual information in a dual-task system. In this experiment, participants work on a game task as the main task and a quiz as the secondary task. The visual appearance is varied in information, colors, positions, and sizes. According to their analysis, they stress the importance of designing a multitasking system from a cognitive viewpoint of human ability. Although our research focuses on the oral information in multitasking system, we share a common belief in the importance of the cognitive viewpoint. Jacob Somervell et al[6] attempt to know how to design information visualizations intended for the periphery and to investigate how quickly and effectively users can understand information visualizations while they are working other tasks hard. They focus on how several factors of a visualization (visual density, presence time, and secondary task type) impact user's abilities to keep working a primary task and to complete secondary tasks related to the visualization. They describe these significant results as follows: (1) We can introduce the peripheral display without reduced performance of main task. (2) Although it is difficult to understand complex visualization, it is effective if they work it with relaxed time pressure and reduced visual information density. Blair Maclntyre et al[7] also think that peripheral display is effective to achieve the multitasking system and try to investigate the design of the peripheral display for that system. They use not only the main display but also the white board as peripheral display which is displayed peripheral information to help their awareness.

Rooms[8] is a multitasking system designed to support task switching and focuses on six characteristics proposed by Banon[9]: reducing the mental load due to switching processes, suspending and resuming of activities, maintaining records of activities, functional grouping of activities, multiple perspective on the work environment, and interdependencies among items in different workspaces. Based on such characteristics, Rooms supports switching tasks more quickly. However, Rooms focuses on switching text information on computer displays, which differs from our approach, we focuses on the information of multiple voices in multiple teleconferences.

We were also stimulated by other researches including the task of teleconferences. Kawahara et al[10] experimented with three overlapped tasks simultaneously. After the experiment, participants answered a questionnaire about overlapping. These tasks include performing personal tasks such as participating in a teleconference and watching a video of a lecture. Although as a result, this study indicated the difficulty of comprehension contents in two overlapping

voices and three simultaneous tasks. Therefore multiple voices in teleconferences should be investigated from a more quantitative approach.

Our research is different from the other researches in that it investigates the comprehension level of two overlapped voices quantitatively and discusses multiple teleconference system based on the results of our experiment.

3 Design Concept

The multitasking researches for office work environment described in the previous section focus on the visual element of switching of tasks. In order to discuss the design of multiple teleconferences, we quantitatively investigate three factors throughout the following experiments: user comprehension levels, psychological loads, and physiological loads of multiple voices.

This experiment is designed to quantitatively evaluate the voice overlapped tasks, assuming two teleconferences. In our experiment, we define the condition of a "Serial" as the most primitive model. This is a condition where two voices are presented one by one, and the voice that gives information is composed of two parts; one in the first half and one in the second half. The result is used as a comparison to the result of overlapped voices. It is also important to discuss the assumed condition of multitasking. For instance, when thinking about attending to two conferences at the same time, we can easily imagine that the difficulty level of oral comprehension depends on the amount of conversation. Therefore, we focus on the rates of overlapping voices in this experiment and use 0%, 20%, 60% and 100% as the overlapping rate of voices. When the overlapping rate is 0% it means that the two voices do not overlap, and when the overlapping rate is 100% it means that the two voices completely overlap. Detailed information about the overlapping rates is explained the nest section.

3.1 Overlapping Rate

When the overlapping rate is 0%, two voices are presented alternately. We show the switching process of these voices in Figure 1.

Story 1 consists of voice part A and B. Story 2 consists of voice part C and D. In this Figure, although the switch from "A → C," "C → B," and "B → D" involves cognitive processing, there is semantic and integrated processing involved especially in "C → B" and "B → D". Meanwhile, the condition of the series above also includes the switch from "B → C". It is different in the sense that integrated processing is not required. When the overlapping rate is 20%, the cognitive load in the human aspect of successive processing is the same as 0%. In addition, however, participants are required to process the overlapped voices and switch their cognition. Switching is done when they change their mind from processing one voice to the other overlapped voice and vice versa. The cognitive load of processing the voice at the overlapping rate of 60% is the same as the overlapping rate of 20%, although the time of the overlapping voices increases. When the overlapping rate is 100%, the voices completely overlap from

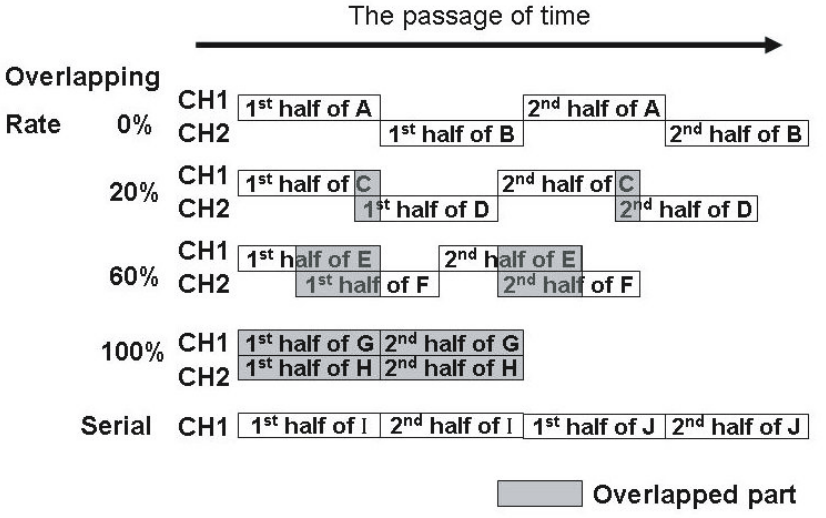

Fig. 1. Overlapping rate of two voices. Story 1 (channel 1 from left speaker) consists of voice part A and B. Story 2 (channel 2 from right speaker) consists of voice part C and D.

the beginning to the end. We hypothesize that the cognitive load of successive processing is the same as the cognitive load when the overlapping rate is 60%, even though participants may be experiencing voice processing on a micro level.

At the end of this paper, we will examine the result of Serial and each overlapping rate.

3.2 Experimental Design

We assume the experimental environment to be multiple teleconferences. We define the rate to which two voices come in succession as the "overlapping rate" and define the time the two voices overlap as "overlapping time".

The application used in our experimental environment is written in JAVA. As part of the experimental environment, we present two overlapped voices to the participants by using two speakers; one on the left and the other on the right hand side. We evaluate the level of comprehension of the voices by making participants solve problems related to the contents of the voices heard from the two speakers after the participants finish hearing the two voices. For instance, when voices of 40 seconds is played with the overlapping rate of 20%, the two voices overlap for eight seconds. We show the overall flow of the experiment in Figure 2.

The experimental environment in our research is composed of two components: two displays to present the problem, a stereo speaker on the right and left side of the participant to output the voices. As the experimental voices, we use the voice of a robotic machine in this experiment. The purpose of this is to remove nonverbal information included in the human voice, which facilitates the

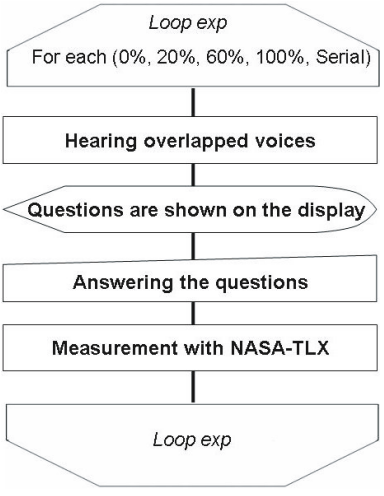

Fig. 2. Overall flow of the experiment

transmission of information. It is thought that the possibility of the multitasking system under difficult conditions can be verified. Our participants are required to answer questions about the content of voices heard from the stereo speaker to their left and right hand side, using desktop computers placed in front of them. They must check what they consider to be the correct answers, from the provided answer groups. The problems include both context problems and keyword problems. Context problems are presented before the keyword problems. The reason behind not presenting both problems simultaneously is to keep participants from anticipating the answer to the keyword problems using information from the answer group of the context questions.

4 Experiment

4.1 The Outline of the Experiment

In order to empirically investigate the comprehension level of the two voices, we test on twenty-eight participants and record their performance throughout our environment. Participants of our experiment are students of Keio University. As previously explained in section 3.1, Story 1 and Story 2 in Figure 1 consists of voice part A and B and part C and D respectively. Each voice part A∼D is 40 seconds long. Story 1 is output from the left speaker and Story 2 is output from the right speaker. Two voices overlap according to the overlapping rate, 20%, 60% and 100%. We investigate the comprehension level, the psychological load and also measure the physiological load by examining the brain waves of randomly chosen 11 participants. We describe the method of each evaluation later on.

First of all, in order to accustom participants to the multitask situation, participants listen to the voice of the overlapping rate 80% for practice. Next,

participants are required to hear the voices of stories. We adopt 0%, 20%, 60%, and 100% as the experimental overlapping rate and Serial as a comparison. The overlapping rate 0% is different from Serial in the point of task switching though the overlapped time is 0 second same as Serial. For the experimental order, we divide our participants into two groups, one in the ascending order (0% → 20% → 60% → 100%) and the other in the descending order (100% → 60% → 20% → 0%).

After that, they solve the problems concerning the contents of the voices displayed on the left and right display. These questions include two types; two context questions that show whether the participants are able to grip the context roughly or not and five keywords that show whether the participants heard the words or not.

The participants check the answer forms that they think is correct from the displays. In addition, they check the convincing level to the answer by five stages on the same displays. After hearing all patterns of overlapped voice and answering questions, we evaluate their psychological load by using NASA-TLX.

Finally, we also give them Serial task that two voices are presented one by one and evaluate their comprehension level and the psychological load.

4.2 Evaluation Method

We use the NASA-TLX as the evaluation method of the psychological load. NASA-TLX is the technique for requesting the load index of the task based on a multi-dimensional average of subjective information. In our research, we use the Japanese Version of NASA-TLX proposed by S.Haga et al[11]. The evaluation of this experiment include measures of the physiological load by examining their brain waves as well as the psychological load by using NASA-TLX. We measure the two loads of eleven randomly chosen participants in the experiment. We measure the α wave peak frequency which indicates the maximum value of the α wave in the brain waves which reflects the influence of mental operations. The α wave peak frequency moves to the high frequency as the work load rises.

5 Results

The result of this experiment include measures of the comprehension level of the overlapped tasks and Serial task as well as the psychological load and the physiological load. Analyzing these measured values separately allows us to examine the following; the comprehension level to the overlapped voices when it is assumed to participate in multiple teleconference, the mental load when participating in multitask system. The following sections summarize the results of the experiment.

5.1 The Result of Comprehension Level

The recorded correctness of the context questions and keyword questions for both overlapped voices and Serial in the experiment are shown in Figure 3 and Figure 4.

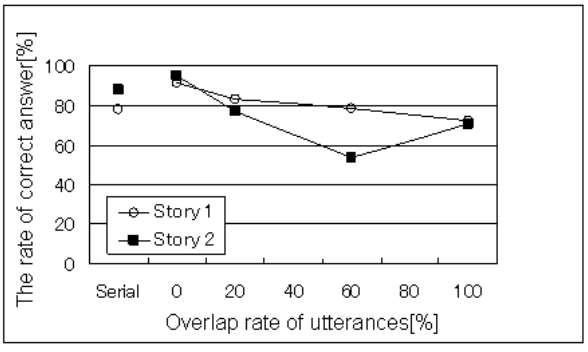

Fig. 3. Correctness of the context questions. In overlapped tasks, story 1 is spoken from the left speaker and story 2 is spoken from the right speaker.

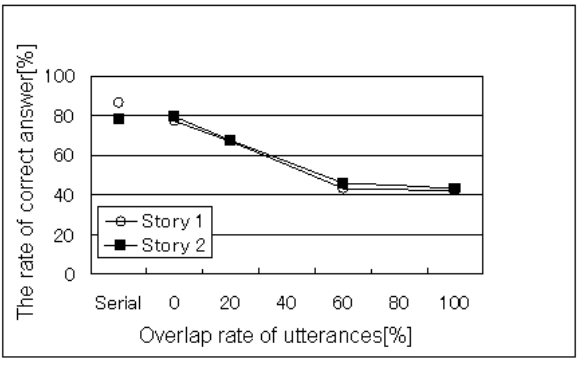

Fig. 4. Correctness of the keyword questions: In overlapped tasks, story 1 is spoken from the left speaker and story 2 is spoken from the right speaker

Figure 3 gives the correctness of the context problems. This result shows the following three factors:

- The correctness of overlapping rate of 0% is 10% higher than the correctness of Serial assumed as the present work style.
- There is a response variance to the correctness of right and left voices in overlapping rate 60%. The correctness of the right voice is lower than the correctness of the left voice.
- The correctness of overlapping rate 100% is higher than 70%.

Figure 4 gives data comparing correctness to keyword questions. As well as the context problem, this result shows the following two factors:

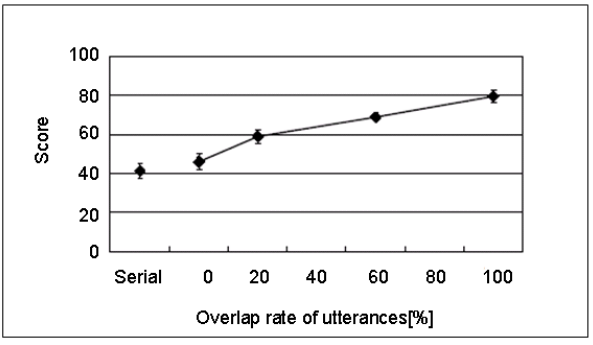

Fig. 5. The result of NASA-TLX

- The correctness of overlapping rate 0% is almost the same as Serial. This means that the correctness of overlapping rate 0% is higher than correctness 80%.
- Little or no difference is found between the correctness of overlapping rate 60% and 100%.

5.2 The Result of Psychological Load

We analyze the result using NASA-TLX to investigate their psychological load to the multiple voices. This result is shown in Figure 5. It indicates that there is highly significant difference ($t(27) = 3.688 \sim 9.280$), $p \geq .01$). This result excludes the combination of Serial and the overlapping rate 0%.)

5.3 The Result of Physiological Load

The result of the α wave peak frequency is shown in Figure 6. This result gives us that there is significant difference (($t(10) = 2.472$), $p \geq .05$)) for only the combination of the overlapping rate 20% and 60%.

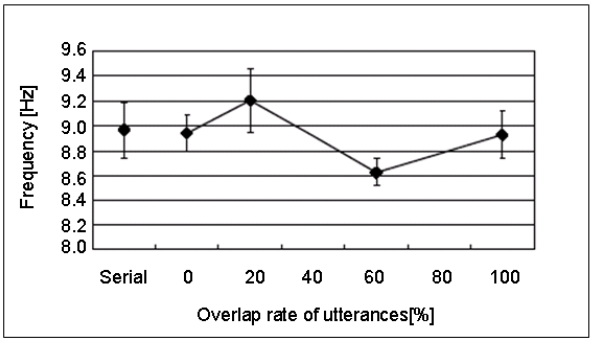

Fig. 6. The result of the α wave peak frequency

6 Evaluation

The results of the experiment are summarized in the following sections.

6.1 The Evaluation of Comprehension Level

Following factors are considered from the result of the correct answer rates.

- There is a possibility that the context can be understood even if two voices overlap completely. In Figure 3, the correctness of overlapping rate 100% is higher than 70%. This result describes participants are able to understand the context roughly when two voices are completely overlapped. This indicates that users who participate in two teleconferences are able to understand both contents.
- In correctness of keywords, little or no difference appears between the correctness of the overlapping rate 60% and 100%. Table 2 shows the detailed correctness values of keywords. From Table 2, we can understand there are actually only several differences between the correctness of the overlapping rate 60% and 100%. This result gives us that little or no difference of comprehension level appears when we compare the case that two voices are overlapped completely with the case that two voices are overlapped halfway. We think overlapping two voices completely is more effective than overlapping halfway because the former case produces reduction of working hours compared to the latter case.

Table 2. The values of correctness for keyword questions. In overlapped tasks, story 1 is spoken from the left speaker and story 2 is spoken from the right speaker.

	Serial	0%	20%	60%	100%
Story 1 (%)	86.4%	77.1%	67.1%	43.2%	42.1%
Story 2 (%)	78.2%	79.3%	67.5%	46.1%	43.2%

6.2 Individual Difference

Although there is no polarization in the comprehension level, we can divide 14 participants into six participants who acquire high correctness and eight participants who acquire low correctness. High correctness means that participants acquire correctness higher than 20% of the average correctness of all participants and low correctness means that participants acquire correctness lower than 20% of the average. We describe this separation in Figure 7.

This result shows us that there is a large difference between the correctness of the left voice and the right voice in the high score group (the difference of correctness is from 8.0% to 21.7%) compared to the low score group (the difference of correctness is from 2.5% to 13.8%). In addition, this figure shows that the participants of the high score group are able to acquire stable correctness

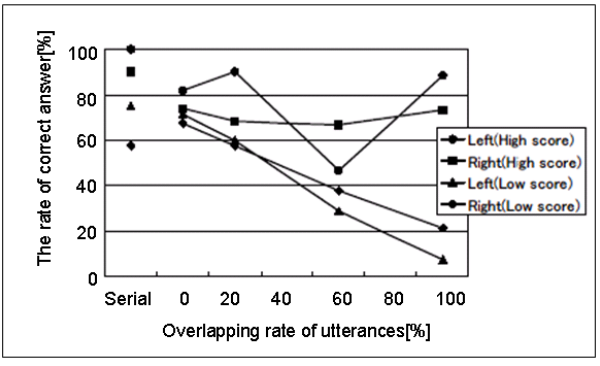

Fig. 7. The result of individual difference

to the right voice in overlapping voices. This result indicates that the participants of the high score group can divide their attention to both left and right.

6.3 The Evaluation of Psychological Load

The result of psychological load indicates that there is a possibility to make their psychological load lower by decreasing of overlapping rate.

6.4 The Evaluation of Physiological Load

The characteristics of the change in the α peak frequency are shown as follows:

- For overlapping rate 0%: equivalent to Serial.
- For overlapping rate 20%: becomes bigger than Serial.
- For overlapping rate 60%: becomes lower than Serial.
- For overlapping rate 100%: equivalent to Serial.

We analyze these results from the aspect of human processing. When the experimental environment has been changed from Serial to the overlapping rate 0%, participants are required to process the switching and the integration of their sense. When it has been changed from the overlapping rate 0% to the overlapping rate 20%, participants are required to process part of the overlapped voices and to shift their mind from the part of overlapped voices to the part of the single voice. We consider these processes are added to the participants as loads. On the other hand, the overlapping rate 20% is changed to 60%, we consider that the shift from the overlapped part to the non-overlapped part directly effects the differences of the correctness between the overlapping rate 20% and 60%. We see that the overlapping rate 60% requires the highest process of cognition. The reason for this is that the participants give up hearing overlapped voices. When it has been changed from the overlapping rate 60% is changed to the

overlapping rate 100%, the cognitive process consists of only processing the part of the overlapped voices. It means they are not required to process the switching, the integration and the shift. This is why the α peak frequency is same as Serial. In addition, considering the result that the peak frequency of the overlapping rate 20% is higher than the overlapping rate 100%, it is supposed that the shift from the overlapped part to the single part is a significant factor from the aspect of physiological loads.

7 Conclusion

In this research, we focused on the fundamental study of participating in multiple teleconferences. Although many researchers focused on the field of multitasking researches, most of the studies aim to visualize dual tasks or to present secondary tasks to the main task. But there is a need to empirically investigate the comprehension level of users and loads of cognition. We prepared an environment which enables the change of the overlapping rate of two story voices and present it to participants.

From our experiment, the following three factors can be described:

- Participants are able to understand the context roughly even if two voices overlap completely. However, it is difficult to understand the keywords, the average of the context correctness of the overlapping rate 100% is 71.4% and the keyword correctness is 42.7%.
- In physiological loads of the overlapping rate 0% and 100%, these loads are almost the same for Serial. And the shift from the overlapped part to the single part is a significant factor as well as the process of overlapped part.
- Individual difference appears. There is a large difference between the correctness of left voice and right voice in the high score group compared to low score group.

This work is placed as a fundamental study that aims at designing multitasking systems.

References

1. O'Conaill, B., Frohlich, D.: Timespace in the workplace: dealing with interruptions. In: ACM Proc. CHI'95, pp. 262–263 (1995)
2. Gonzales, V.M., Mark, G.: Constant, Constant, Multi-tasking Crazines. In: Proceedings of CHI'04, pp. 113–120 (2004)
3. Smith, D.: Multitasking undermines our efficiency,study suggests. In: Proc. ACM SIGCOMM'95, pp. 342–356 (1995)
4. Schumacher, E.H., Seymour, T.L., Glass, J.M., Fencsik, D.E., Lauber, E.J., Kieras, D.E., Meyer, D.E.: Virtually perfect time sharing in dual-task performance: Uncorking the central congnitive bottleneck. Psychological Science, 101–108 (2001)

5. Jacob, S., McGrickard, D.S., Ndiwalana, A., Narth, C., Pryor, J., Tessendorf, D.: Secondary Task Display attributes-Optimizing Visualizations for Cognitive task suitability and interference avoidance. In: ACM Proc. VisSym'02, pp. 165–171 (2002)
6. Jacob, S., McCrickard, D.S., North, C., Shukla, M.: An evaluation of information visualization in attention-limited environments. In: Proceedings of the symposium on Data Visualisation '02, pp. 211–216 (2002)
7. MacIntyre, B., Mynatt, E., Voida, S., Hansen, K.M., Tullio, J., Corso, G.M.: Support for multitasking and background awareness using interactive peripheral displays. In: Proceedings of the 14th annual ACM symposium on User interface software and technology, pp. 41–50 (2001)
8. Card, S.K., Henderson Jr., A.: Tivoli: A Multiple, Virtual-Workspace Interface to Support User Task Swetching. In: Proc. SIGCHI Bulletin'87, pp. 53–59 (1987)
9. Banon, L., Cypher, A.: Evaluation and analysis of users' activity organization. In: Proc.ACM CHI'83, pp. 54–57 (1983)
10. Kawahara, T., Kobayashi, T., Takeda, K., Minematsu, N., Ito, K., Yamamoto, M., Utsuro, T., Shikano, K.: Sharable software responsitory for Japanese large vocabulary continuous speech recognition. In: Proc. ICSLP'98, pp. 3257–3260 (1995)
11. Haga, S., Mizukami, N.: Japanese version of NASA Task Load Index: sensitivity of its workload score to difficulty of three different laboratory tasks. Japanese Journal of Ergonomics 32, 71–79 (1993)